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The oolitization rate determination of bentonite moulding mixtures

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Abstract

Bentonite mixtures belong and will always belong among the most widespread sand mixtures for the “green sand” technology of castings production. This technology’s essential advantage is bentonite mixtures application reversibility in the closed circulation after composition modifications and circulation losses replenishment. After the casting of a mould, the surrounding sand mixture is strained by the solidifying casting heat and bentonite degradation occurs. In case of appropriate conditions the oolitization occurs. This phenomenon is specific only for bentonite-bonded mixtures. The oolitization of opening material silica grains brings a number of negative as well as positive features with it. It is not only a technological problem but economical and ecological as well because for minimization of mixture regeneration with a help of new sand it is necessary to know bentonite mixtures quality control tools even in term of the oolitization rate. This paper deals with the description of undemanding physical method of the oolitization rate evaluation with a help of powder density assessment and its examination with actual sand mixtures which were obtained from the Czech Republic foundry plants. There are foundry plants of heavier weight castings and in one case there was an operation where bentonite mixtures regeneration was applied. Moreover, the oolitization effect on metal penetration in test castings was verified.

Keywords: Castings defects; Environment protection; Oolitization; Bentonite; Moulding mixtures.

1. Introduction

At the present time, more than 70% [1] of worldwide castings production is made into synthetic bentonite mixtures whereas castings rough weight keeps increasing. The reality of ever increasing castings weight sets enhanced demands upon the bentonite mixture, both on the binder thermostability and the silica sand.

During casting to bentonite mixtures considerable heating of the sand mixture occurs due to fluid, solidified and cooling metal heat, especially in casting’s close surroundings. Mould’s thermal load is influenced particularly by the casting’s shape and mould/metal weight rate, the casted material sort and its casting temperature.

By warming of smectite group clays a number of processes happen which change their structure and properties. Processes proceeding are e.g. dehydration, dehydroxylation and crystalline grid failure connected with new phases formation.

From 500-600°C bound water loss occurs and active bentonite changes into metakaolinite and at higher temperatures a chamotted layer is formed on silica grain surface. The formed burnt-out layer is tightly thermally fixed onto grain and it cannot be transformed into the plastic state with a help of water anymore. The grain surface is very porous with a big number of cracks and cavities. During the bentonite mixture circulation the sand grain is covered again with a new binder which passes through the same changes due to the heat again and thus the layer thickness on silica grains growths. This phenomenon is called oolitization [2].

The oolitic layer has different properties from the original binder. It is very porous and features increased water absorbability. Then, in such cases it is essential to apply higher water content for reaching the bentonite mixture optimal moisture. The free water increased content can lead to oxidation of carbon additives pyrolysis products, thereby pyrolyze carbon (glazed carbon) amount reduction which leads to the inclination towards surface metal penetrations at graphitizing metal alloys. The sand mixture increased moisture takes a negative effect not only on the green sand binding property decrease but on increased gas porosity as well. According to Hofmann [2], higher water concentration in these grains occurs thanks to oolitized layers porosity and this uneven water distribution in the mixture contributes to coarse surfaces of castings. At the sand mixture higher moisture content the penetration due to water explosion may happen. On the contrary, Kurokawa and coll. [3] sees a favourable feature in the increased water absorption through oolitized grains because Oolites prevent the sand mixture from the total desiccation. By this, bentonite mixtures keep good forming characteristics and mixtures are stable during circulation.

The thermal conductivity decrease, which is the oolitization process consequence, shows itself by the temperature increase on the mould' front which boosts metal penetrations occurrence as well [2].

On the contrary, oolitization takes favourable effect against stress defects. Oolites turn soft during casting, they compensate the silica sand thermal expansion and therefore there is a reduction of casting stress defects, e.g. scabs, fins, sand buckles.

Reversely, with a larger amount of oolitized grains, the pure silica content in the mixture decreases. SiO_2 oolitized grains feature lower heat resistance, first they are melted by molten metal heat and additionally binary-type silicates $FeO\text{-}SiO_2$ (e.g. fayalite) grow, the source of penetrations and burn-ons origin.

In scientific literature there are methods of oolitization assessment presented, both physical (pycnometric - specific weight determination, RTG) but also chemical methods:

- Dissolving of coatings in orthophosphoric acid;
- Dissolving of coatings with a help of hydrofluoric acid.

During verifying of these procedures it was shown that chemical methods show out a large variance of values [4] and the pycnometric determination is time consuming for foundry plants.

A new oolitization assessment procedure was elaborated at the Department of Foundry Engineering, Faculty of Metallurgy and Materials Engineering, VŠB-Technical University of Ostrava.

2. Empirical part and results discussion

The proposed methodology results from the fact that the silica grain and the oolitized layer on the grain surface have a different specific weight, i.e. 2.65 or 2.0 g/cm^3. The sample makes use of opening material modification after the granulometric analysis – preferably in two closely separated fractions. Very small amount of opening material is sufficient for the powder density assessment because the powder capacity is determined in 2 ml pipette by vibration at a suitable equipment (e.g. vibratory screen) to a minimal value (vibration time 5 – 8 min). The assessment sensitivity is 0.08 – 0.15%.

2.1. Developed methodology verification on model cases

The model bentonite mixture (7 weight % of binder - Bentovet K) was annealed at 900°C/2 hours. After the cooling, the sand mixture was deprived of washable away in water substances by flushing. To the opening material modified in this way bentonite was added again, the mixture was prepared, the annealing followed again and we repeated this procedure for 5 times to obtain various silica grain oolitization rates. Measurements results are displayed in Fig. 1.

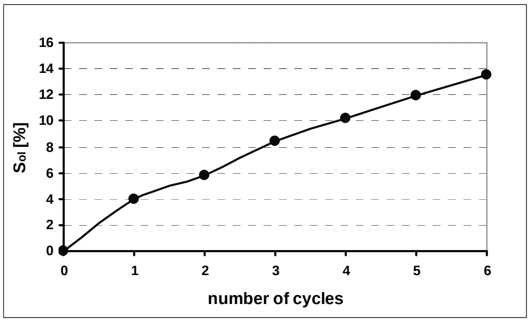

Fig. 1. Increasing oolitization rate with the number of circulations

From the graph presented there is evident the increasing oolitization rate (S_{ol}) up to 14% after the 6th circulation. Opening material surface changes in relation to the number of circulations are evident in SEM pictures (Fig. 2a, 2b, 2c).

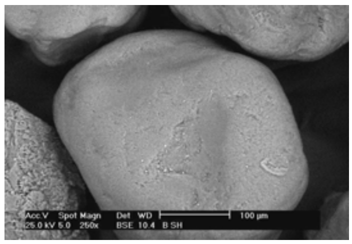

Fig. 2a.
Silica sand
Š-27 OT ŠH, SEM

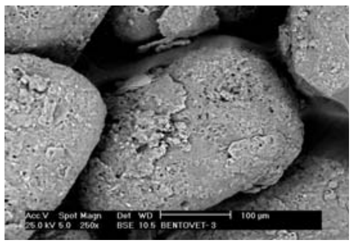

Fig. 2b.
Model sand
(third circulation)
surface detail, SEM

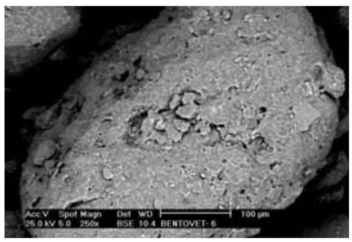

Fig. 2c.
Model sand
(sixth circulation)
surface detail, SEM

In Fig. 2a (pure silica sand) the surface is smooth, after the 6th circulation (Fig. 2c) there can be seen residuals of the oolitized layer which was not removed by flushing and then even grain conglomerates origination. Samples after the 6th circulation were analyzed by means of diffraction analysis RTG for the purpose of oolitized layer composition assessment. Results demonstrated that there is not a mullit layer there but only a transient metakaolinite compound

2.2. The oolitization effect on the surface quality of the casting

From the oolitized opening material samples there were cores prepared which were used for the test castings production. The test cores were prepared both from oolitized opening material and from pure silica sand Š-27 OT ŠH. Bentovet K. bentonite was used as the binder for these cores. A cylinder casting (Fig. 3), 180 mm diameter and 100 mm height, (equipped with an exothermic head of 450 mm height) is formed by 4 wedge-shaped cores stamped in core boxes to the same volume weight. There were always two cores (pure silica sand) and two cores (oolitized opening material) applied in the experiment.

Carbon steel (Tab. 1) was used as the material for the test castings production. The casting temperature was 1,620°C.

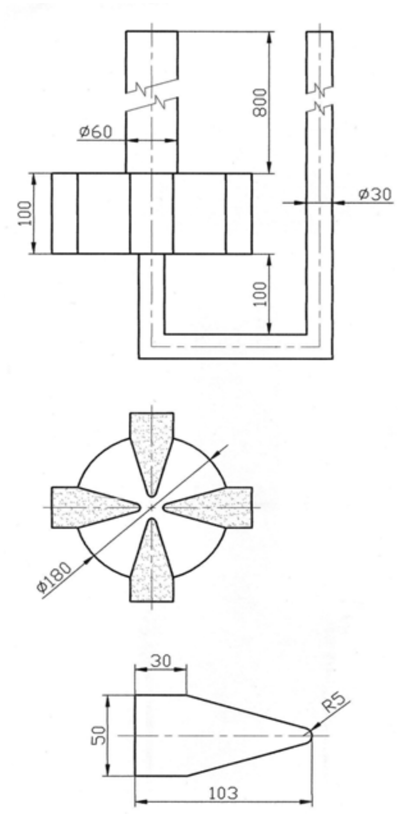

Fig. 3 VSB TU Ostrava test casting [mm]

Table 1.
Casted steel chemical composition

	C	Mn	Si	P	S	Cu
wt.%	0,50	0,47	0,08	0,095	0,018	0,115

After casting, the casting was cut up (Fig. 4) in a half of the cylindrical part's height and there were burn-on areas evaluated on the section with a help of AutoCAD program.

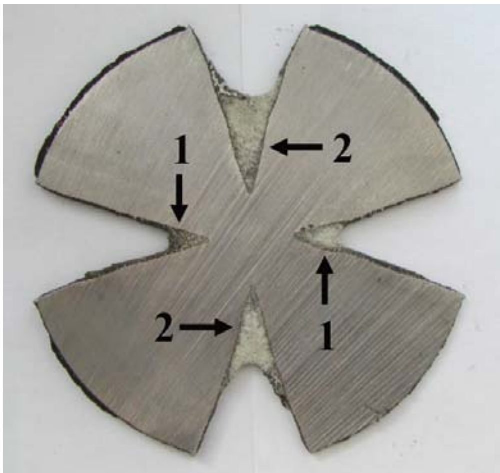

Fig. 4. Evaluated section example
1 – new sand, 2 – model sand (oolitization rate 9%)

Table 2.
Oolitization rate effect on cores penetration

oolitization rate [%]	0	3	5	9
penetration [%]	12	11	21	32

Results obtained by test castings evaluation are displayed in Tab. 2. In total, there were 3 heats realized experimentally through which 3 pieces of castings were prepared where cores were made of the pure silica sand and opening material with the oolitization rate 3, 5 and 9%. The penetration increased occurrence at the sample with 9% oolitization was 20% higher compared to the core with the pure silica sand.

2.3. Verification in practical cases

Mixtures samples from foundry plants were evaluated by a powder density method.

Foundry Plant A

This is an iron-foundry (castings up to 400 kg) using the bentonite mixture where the silica sand (Š-22 ŠH) serves as the opening material. The natrium-enriched bentonite SABENIL is used as a binder. Cores are made from Š-27 OT ŠH silica sand by the Cold-Box method.

Table 3.
Oolitization rate assessed at samples from the foundry plant A

Foundry Plant A	powder density (0,4–0,315) mm	powder density (0,25–0,16) mm
	$g.cm^{-3}$	$g.cm^{-3}$
new opening material	1,7018	1,7256
mixture opening material	1,6872	1,6922
oolitization rate [%]	0,86	2,0

Foundry Plant B

This is a foundry plant using 100% of the bentonite mixture reclaim (pneumatic regeneration SIMPSON) in combination with the model mixture at castings' exposed spots (Keribent RF bentonite), regeneration up to 6% (from cores). Castings up to 900 kg weight, walls thickness 12 – 30 mm, material – carbon steel and casting temperature 1,600°C.

Table 4.
Oolitization rate assessed at samples from the foundry plant B

Foundry Plant B	oolitization rate (0,355-0,5) mm	oolitization rate (0,25-0,355) mm
	%	%
May 2006	0,67	0,53
December 2007 (reclaim)	0,06	- 0,01
December 2007 (mould's front)	0,76	3,24

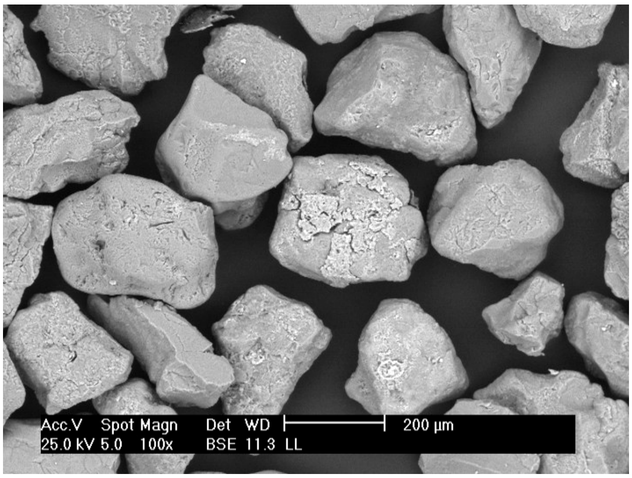

Fig. 5. Plant mixture opening material

Plant mixtures samples demonstrated (Tab. 3, 4) that the oolitization rate is very low and it cannot have any significant influence on the castings surface quality and that even in case of the foundry plant B where the sample was taken from the mould's front (Tab. 4). The oolitization rate was only (0.76-3.24%) in this case which is deep below the boundary where the oolitization affects the surface quality. In Fig. 5 there is the plant mixture opening material shown, very low foulness of the silica sand is evident in this picture as well.

4. Conclusions

The study dealt with the oolitization of opening materials silica grains and its consequences on the bentonite mixture quality. The oolitized sand samples were obtained both by means of oolitization process modeling and from the plant mixture.

The oolitized opening material proved higher inclination to penetration which was examined with test castings.

The results achieved at plant samples have shown very low level of the oolitization rate which proves the high level of mixture regeneration by means of silica sand from cores.

The new physical method was applied and verified – the powder density assessment. In real conditions it is essential to use only narrow granulometric fractions of opening material which we can obtain from the vibrating analysis and thus it is possible to combine both of these processes properly.

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